Industrial Materials For The Future

Project Fact Sheet

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VIRTUAL WELD-JOINT DESIGN INTEGRATING ADVANCED MATERIALS AND PROCESSING TECHNOLOGIES

BENEFITS

➤ Reduced welding energy, reduced rework, and reduced welding emission.

➤ More efficient mining hauling trucks and loaders, increased product life, more-efficient manufacturing of welded components, and improved life cycle.

➤ Increased competitiveness of U.S. manufacturing base.

➤ Accelerated application of advanced steels.

APPLICATIONS

Efficient and metallurgically sound weld joints for the following industries:

➤ **Forest Products,**

➤ **Heat Treating**,

➤ **Mining,**

➤ **Petroleum,** and

➤ **Steel.**

AN INTEGRATED MODELING APPROACH TO DESIGN HIGH-PERFORMANCE WELD JOINTS CAN IMPROVE THE PERFORMANCE OF WELD JOINTS USED IN EARTHMOVING EQUIPMENT

In the United States, welding is utilized in about fifty percent of the industrial and commercial products that make up the GNP. The integrated modeling approach to be developed in this project can be beneficial to the welding, steel, heat treating, and other industries. The developed technology will also be applicable to various other industries related to materials processing (e.g. the chemical industry) through the participating organizations.

The project will integrate existing modeling tools with new enhancements to develop a systematic microstructure-level modeling approach for the design of a high-performance weld joint. The systematic modeling approach will lead to an optimized weld joint design by considering the combined effects of weld bead geometry, microstructure, material property, residual stress, and the final fatigue strength. The computer–aided virtual weld joint design will also enable improvement of the manufacturing quality, resulting in increased manufacturing productivity and reduced energy consumption for welding and reduced welding emissions.
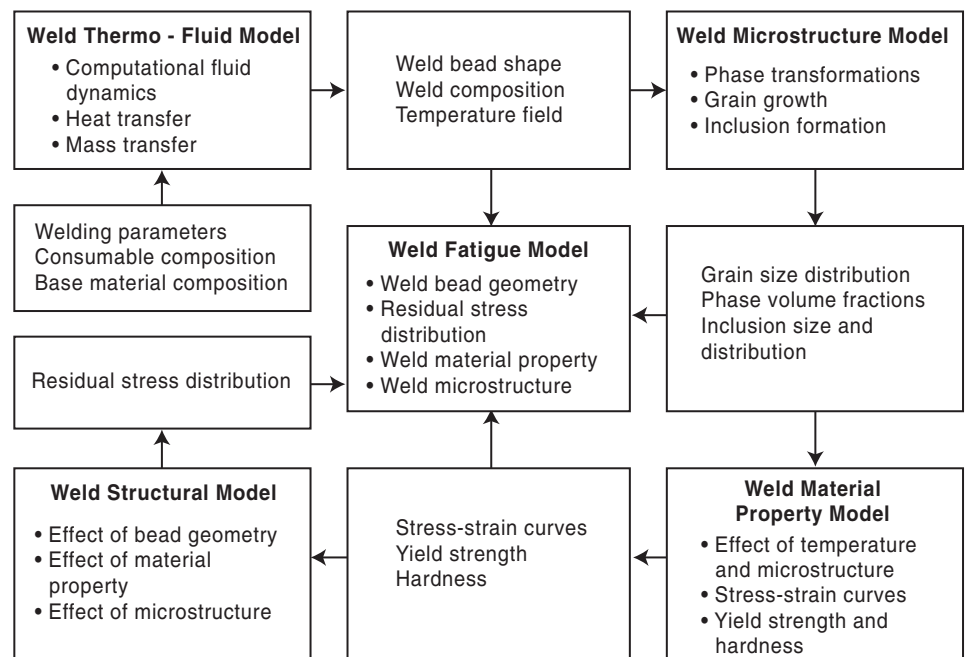
Flow chart of the integrated modeling approach for virtual weld joint design

Project Description

Goal: The primary goal of this project is to use an integrated modeling approach to increase weld joint service performance by 10 times and to reduce energy use by 25 percent through performance and productivity improvements. This integrated model will address base material selection, weld consumable design, welding process parameters optimization, weld residual stress management, and fatigue resistance improvement.
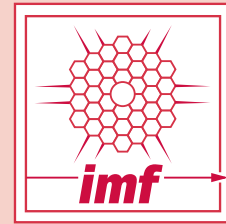
Issues: In many fabricated structures, weld fatigue is the limiting design factor affecting the durability and reliability of the product. Previous work shows that the fatigue life of a welded joint can be significantly improved (10×) by obtaining desired weld bead shape, residual stress distribution, and microstructure. Current weld models, however, deal with only one or two individual physical phenomena and cannot directly quantify their effects on residual stresses or fatigue performance. In turn, inadequate understanding of microstructure evolution and coupling effects on transformation plasticity prevents development of an adequate residual stress model for applications in a broad range of materials. A systematic modeling approach is required to simulate these effects and to allow weld joints to be designed for optimum fatigue strength.

Approach: As shown in the figure, the integrated modeling approach combines five sub-models: a weld thermo-fluid model, a weld microstructure model, a weld material property model, a weld residual stress model, and a weld fatigue model. The integrated model is thus based on interdisciplinary applied sciences, including heat transfer, computational fluid dynamics, materials science, engineering mechanics, and material fracture mechanics.

Potential payoff: Caterpillar currently uses high strength steels in less than 5% of the total weight of manufactured structures due to the limitation of weld joint fatigue performance. This project will develop a weld joint design tool that will impact 80% of current fabricated structures. The results are expected to lead to an increase in use of high strength steel by 10× (or 50% of total weight) in high-performance structures. This will position the U. S. steel, heat-treating, and welding industries to increase the production/processing of "high-performance" and advanced materials.

Progress and Milestones

➡ Develop simulation tool to predict weld bead profile.
➡ Calculate various phase volume fractions and grain sizes as functions of the composition and thermal profiles.
➡ Develop a property model that will incorporate the thermal history, chemical composition, and microstructures of the material to predict the stress-strain curves at various temperatures, including yield stress, hardening behavior, and hardness.
➡ Modify 3-D residual stress model for weld joint fatigue life prediction to incorporate microstructure and properties.
➡ Integrate sub-models and perform parametric study for fatigue model.
➡ Validate residual stress models with experimental measurements.